Third United Nations International Conference on the Peaceful Uses of Atomic Energy

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Abstract

HARDENING OF FACE CENTERED CUBIC METALS DUE TO REACTOR IRRADIATION

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The present paper gives a survey on some recent experimental work on the changes of the mechanical properties of f.c.c. single crystals due to fast neutron irradiation in a nuclear reactor. It is similar in scope to the contribution of one of the authors (J.D.) to the IAEA Symposium on Radiation Damage in Solids and Reactor Materials, Venice, 1962. However, the present report is based on more detailed results and covers a more extended series of experiments, including irradiations at ambient reactor temperature as well as irradiations at helium temperatures, normal tensile tests, creep test, measurements with changes in temperature and strain rate and electron microscope studies of slip lines. The low temperature experiments were carried out in the low temperature irradiation facility of the Munich Research Reactor. The main results are the following:

(a) Low temperature irradiation and post-irradiation annealing experiments support the view that the increase of the yield stress in heavy f.c.c. metals, like copper, is caused by radiation induced depleted zones, which impede the motion of dislocations, as originally proposed by Seeger.

(b) The annealing behaviour of the yield stress of aluminium after irradiation at low temperature is different from that of copper. It can be accounted for by the assumption that primarily single point defects dispersed in the lattice act as obstacles to the motion of dislocations. Apparently in this metal depleted zones are not formed or are less stable than in copper.

(c) Neither in copper nor in aluminium indications for a source hardening mechanism (locking of the dislocation sources by point defects) could be obtained from yield stress measurements.

(d) The saturation effects, revealed by the dose dependence of the yield stress of Cu, are almost independent of the irradiation temperature (between 4° and $300^{\circ}K$). The saturation is in accordance with measurements of the electrical resistivity and can be accounted for by athermal radiation annealing processes.

(e) For a more comprehensive interpretation of the temperature and strain rate dependence of the yield stress of the heavy metals, a size distribution and possibly deviations from a random arrangement of the depleted zones have to be taken into account.

(f) Further evidence of the previously reported differences in the deformation behaviour of heavy metals after low and high irradiation doses has been obtained by various experimental techniques. These differences can be interpreted in a tentative way.

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Abstract

Fission Gas Release from Solids with Special Regard to UO_2, UC, and ThO_2 Single Crystals*

by

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Neutron irradiation of special solids results in single atoms of rare-gases dispersed in the solid system. By observing the kinetics of the diffusion and final release of the rare-gas stoms, structural and chemical changes during thermal treatment of the solid can be observed and investigated (Zimen [1]). In fissionable solid materials and at higher burn-up the formation of rare-gas atoms and bubbles implies a mechanical stress of the fuel elements and jackets, and a change of reactivity by the build-up of Xe-135. To study the mechanisms of rare-gas diffusion in and the release from solids the following investigations were conducted:

1. Theoretical studies of the kinetics of ideal rare-gas diffusion in case of post-activation diffusion (PAD) experiments (Inthoff, Zimen [2] , Gaus [3]) and in case of dum-activation diffusion (DAD) or in-pile experiments (Flügge, Zimen [4] , Gaus [5]).
2. Development of proper methods for the evaluation of PAD and DAD measurements in case of ideal and non-ideal gas release (Zimen [6] , Lagerwall, Zimen [7] , Lagerwall, Schmeling [8]).

* A large part of the work referredto in this survey was accomplished under EURATOM contract in the framework of the JOINT EURATOM/UNITED STATES PROGRAM.

3. Development of experimental techniques for PAD experiments with corrosion-sensitive materials at high temperatures (Schmeling, Felix [9], Felix, Schmeling, Zimen [10]).

4. Experimental investigations with model systems. Up to now results have been obtained for Argon diffusion in single crystals and poly-crystalline material of CaF_2 (Lagerwall [11] , KF and KCl (Richter, cf. [10]).

   In silver samples containing small amounts of Li the simultaneous diffusion of H-3 and He could be investigated and interesting differences in the behaviour of the two gases were observed (Migge, Wagener, [12]).

5. Experimental investigations with fuel materials. The results hitherto obtained are concerned with UC in graphite matrix (Schmeling [13]) and with single crystals and polycrystalline material of UO_2, UC, and ThO_2 (cf. [10]). The unpublished results concerning these systems will be described in the report.

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